ON THE ORIGIN OF THE SPERM-BLASTOPHORE OF SOME AQUATIC OLIGOCHAETA.

SHINKISHI HATAI.

THE first investigator to discuss the origin of the sperm-blastophore in Oligochaeta was Bloomfield.[1] His work was done mostly on living material, although he supplemented it to some extent by preparations mounted in glycerine. He studied the external features only. Later, Calkins[2] published a detailed account on the same subject, his views being opposed to those of Bloomfield. Both of these writers made their observations upon Lumbricus terricolae. A more complete statement of their respective views will be given on a later page.

In the Limicolae the origin of the sperm-blastophore has not yet been studied, although some work on the structure of Limnodrilus Gotoi[3] and Vermiculus limosus[4] of this group has been published recently. These species are common in Japan. The material used in the present study was fixed in Perenyi's fluid and corrosive sublimate. The stains used were Kleinenberg's haematoxylin, Rawitz's haematoxylin, and borax carmine.

The present article deals only with the formation of the sperm-blastophore. The various stages in its development may be described advantageously in the following order:

1. *Spermatogonia.*—A section of the testis (Fig. 1) shows three stages in the maturation of the spermatogonia, namely: (*a*) The cells at and near the proximal end of the testis are

[1] Bloomfield, E., "On the Development of the Spermatozoa. 1. Lumbricus," *Quart. Journ. Micr. Sci.* Vol. xx. 1880.

[2] Calkins, G. N., "The Spermatogenesis of Lumbricus," *Journ. of Morph.* Vol. xi. 1895.

[3] Hatai, S., "On Limnodrilus Gotoi (n. sp.)," *Annotationes Zoologicae Japonesis.* Vol. iii, Part i, 1899.

[4] Hatai, S., "On Vermiculus limosus," *Annotationes Zoologicae Japonesis.* Vol. ii, Part iv, 1896.

somewhat polygonal, firmly connected, and possess comparatively small nuclei. (*b*) The cells of the central part are larger than the former, becoming gradually spheroid and more loosely connected; the nuclei are larger, and the peritoneal membrane of the testis disappears in this region. (*c*) At the free ends of the testis the cells present completely spherical forms, and are so loosely connected that they may be easily detached. The spermatogonia have conspicuous nuclei. Each fully matured spermatogonium has one large nucleus, and is not multinucleate, as in Lumbricus (Calkins).

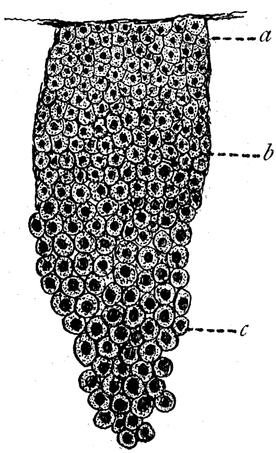

FIG. 1.

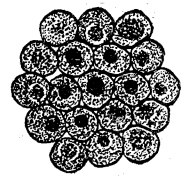
FIG. 2.

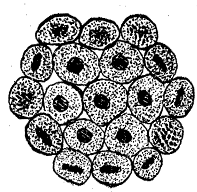
FIG 3.

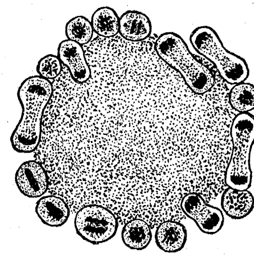
FIG. 4.

2. *Spermatocyte* (Figs. 2, 3). — The primordial germ-cells, or spermatogonia, when fully matured drop from the testis; sometimes one or two, but usually many at the same time, afterwards swelling up gradually. When they are first detached from the testis, no changes are noticeable, but with the beginning of cell division the following nuclear changes are observed: The nucleus of each cell in the outer layer moves inward toward the center of the cluster, as shown in Fig. 2. Each nuclear membrane disappears, while the chromosomes become distributed evenly throughout the nucleus. Soon the chromosomes collect in the equatorial plane (Fig. 3) and undergo division by the usual method of karyokinesis (Fig. 4). The spermatid arises after two or more such divisions. The cells at the central part show no signs of change, but remain in the resting stage.

Usually, after the peripheral cells have divided, the central cells become granular and appear homogeneous; the nuclei and cell membranes can no longer be distinguished (Fig. 5). In other words, the central cells degenerate at this period and become transformed into a cushion for the spermatozoa. This cushion is called the "sperm-blastophore" by Bloomfield.

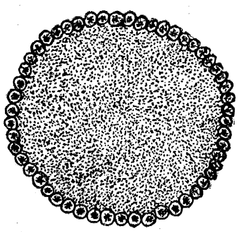

FIG. 5.

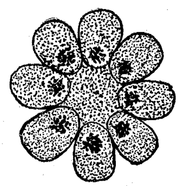

FIG. 6.

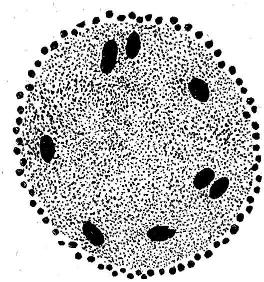

FIG. 7.

(Occasionally this transformation of the central cells occurs previous to the division of the peripheral cells, Fig. 6). The daughter-cells produced by the several divisions of the spermatocyte become half the size of the mother-cells, and retain this size throughout the stages of formation of the spermatozoan. These half-sized cells are the spermatids.

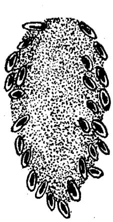

FIG. 8.

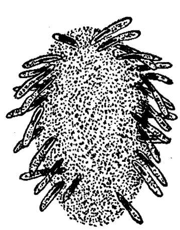

FIG. 9.

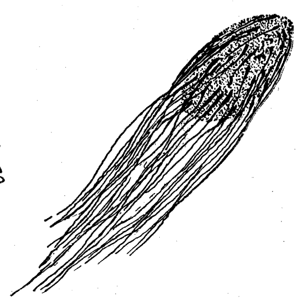

FIG. 10.

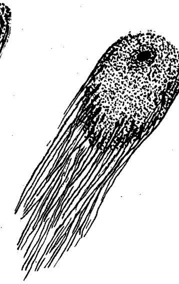

FIG. 11.

3. *Spermatids.*—The spermatids encircle the blastophore (Fig. 5), which changes to a spherical form and becomes more conspicuous than in the former stage. The spermatids now undergo repeated cell division, producing an enormous number of new spermatids (Fig. 7), which gradually elongate (Figs. 8, 9), and finally become tailed spermatozoa (Figs. 10, 11). The

tails of the spermatozoa all turn in one direction, as depicted in Figs. 10, 11. While these changes of the spermatids are in progress, the blastophore itself changes its form from spheroid to oblong and sometimes becomes spindle-shaped (Fig. 12).

As shown above, the central cells of the original cluster degenerate to form the sperm-blastophore, which appears as a homogeneous substance. It should be here stated that cases have been observed in which several nuclei were scattered through the homogeneous substance of the blastophore, but rarely a complete cell, as shown in Fig. 13. The question arises as to the origin of these nuclei or cells. It seems reasonable to suppose that they are simply belated portions which have not yet been transformed into the homogeneous mass. Fig. 7 shows a condition in which only the nuclei remain. At no time during the formation of the blastophore has a proliferation of the central cells been observed.

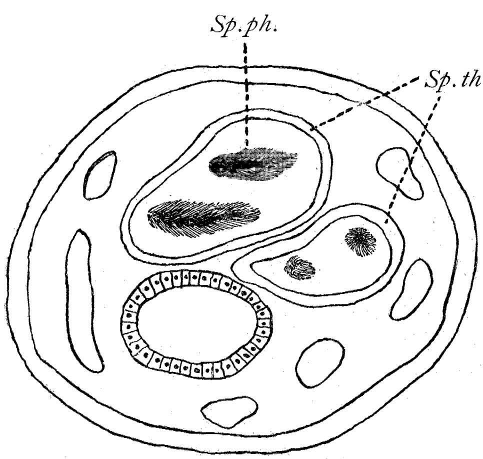

FIG. 12.

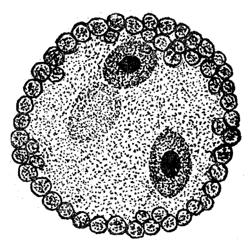

FIG. 13.

The spermatophore becomes slightly modified in passing from the sperm-sac to the spermatheca, as shown in Figs. 12, 14, 15. It is to be noticed that the tails of the spermatozoa turn spirally; this being a secondarily acquired character occasioned by its passage through the sperm-duct. Following these changes, the sperm-blastophore becomes more or less spindle-shaped; it also decreases in size. In the cross-section of a spermatophore a central canal is generally to be seen, as represented in Fig. 15. The blastophores are at first com-

paratively large (Figs. 8–11); they gradually decrease, and finally disappear, as shown in Fig. 15. It would appear, therefore, that the blastophore is produced by the degeneration of the central cells, and that it not only acts as a cushion, affording a means for conveying the spermatozoa, but also serves as nourishment for them.

Bloomfield's principal results, as briefly summarized by Calkins, are as follows:

"1. The early germ-cell is not entirely used in the formation of spermatozoa; a central part remains passive, and serves to carry the developing spermatic cells. This central part is called the sperm-blastophore, and may or may not be nucleated.

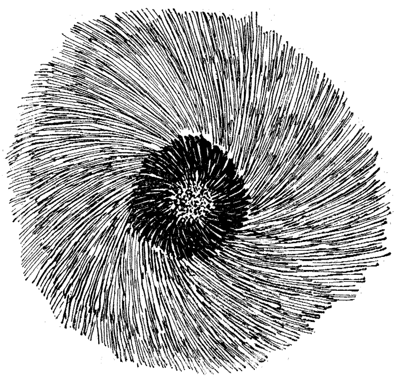

FIG. 14.

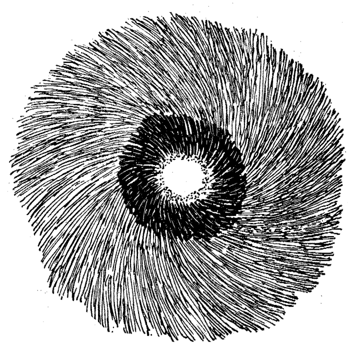

FIG. 15.

2. The sperm-blastophores increase by division while in the testis, and disappear, probably by atrophy, after the spermatozoa leave it.

3. The blastophore corresponds to the nucleated supporting cells (Sertoli's cells) of the frog and salamander.

4. The large nucleus of the early sperm-cell divides many times to form secondary nuclei, which stand out around the central mass, or blastophore, of the generating spheroid with very little protoplasm clothing them. These nuclei become the rod-like heads of the spermatozoa.

5. The protoplasm collects in a small cup, or knob-like mass, at the distal end of the developing cell, and from this grows out the long vibratile tail of the spermatozoan. (This 'mass' must be the archoplasm of the spermatid.)"

Calkins summarized his own results as follows:

"1. A multinucleated cell is formed in the testis; this represents a group of the earliest spermatic cells or spermatogonia. Each spermatogonium gives rise to several spermatozoa.

2. The nuclei arrange themselves around the periphery of the multinucleate cell; cytoplasmic cleavages then ensue between the nuclei, as in the centrolecithal egg. The cleavage grooves deepen until the nuclei are separated from the central mass of cytoplasm by mere filaments.

3. The residual mass of cytoplasm thus formed (the blastophore) is not nucleated, and cannot be compared with a Sertoli's cell in function, form, or mode of origin. It finally disappears. The blastophore furnishes perhaps the chief source of food supply for the parasites — monocysts — which live in the seminal vesicles. A possible explanation of the function of the blastophore is that of superfluous nutritive cytoplasm, the vital protoplasm having gathered around the nuclei."

Thus it will be seen that Bloomfield and Calkins hold very different views regarding the blastophore. The former considers it as having a nutritive or feeding function. It carries developed spermatozoa, and is to be regarded as the homologue of Sertoli's cell. The latter maintains that the blastophore is merely an excess of cytoplasm and not a true cell; therefore it cannot be homologous with the Sertoli cell.

The question as to the structure and function of the blastophore in Lumbricus can be decided only when we learn its true origin. In the present work on the two new species of Limicolae, it appears that the blastophore originates through the degeneration of certain of the primordial germ-cells which lie at the centers of the clusters of spermatogonia given off from the testes.

It serves not only for carrying developed spermatozoa, but for their nourishment as well. Thus it arises from *definite cells*, and, as Bloomfield has suggested, may be compared to the *Sertoli's cell.*

HULL ANATOMICAL LABORATORY,
UNIVERSITY OF CHICAGO.